

Appendix F

Evaluation of Future Risk Reduction for Various Soil Removal Alternatives at the 216-Z-1a Tile Field, 216-Z-9 Trench, and 216-Z-12 Crib

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Terms

ARARs	applicable or relevant and appropriate requirements
CCU	Cold Creek unit
CERCLA	<i>Comprehensive Environmental Response, Compensation, and Liability Act of 1980</i>
COC	contaminant of concern
COPC	contaminant of potential concern
EPA	U.S. Environmental Protection Agency
EPC	exposure-point concentration
OU	operable unit
RESRAD	RESidual RADioactivity (dose model)
RTD	removal, treatment, and disposal
UCL	upper confidence limit

Appendix F

Evaluation of Future Risk Reduction for Various Soil Removal Alternatives at the 216-Z-1a Tile Field, 216-Z-9 Trench, and 216-Z-12 Crib

F1.0 Introduction

The human-health risk assessment for the 200-PW-1/3/6 Operable Units (OU) (see Appendix A) evaluated risks under current conditions (industrial land use, assuming the existing institutional controls with adult workers as the population potentially exposed) and future conditions (unrestricted land use if institutional controls fail in the future). The unrestricted land use scenario assumes that land use controls will remain in place for 150 years; after that time there is assumed to be a failure of institutional controls so potential exposures to a future residential farming population (adults and children) and a future working population (well drillers) are hypothetically possible.

This appendix summarizes the results of the baseline risk assessment from Appendix A for the future well driller and future subsistence farmer from soil contamination at the 216-Z-1A Tile Field, the 216-Z-9 Trench, and the 216-Z-12 Crib (subsistence farmer risks only). [Note, the 216-Z-12 Crib was not evaluated in Appendix A; however the same methodology that was used in the baseline risk assessment was employed to estimate subsistence farmer risks at this site.] The remaining sections of this appendix evaluate residual risk for the final contaminants of potential concern (COPC) if different depth intervals of soil were to be removed from these three waste sites (in general, shallower depths have higher concentrations). This appendix includes discussion of the selection of COPCs for the three waste sites, estimated soil concentrations for the COPCs assuming varying depths of soil removal, and calculation of health risks based on the remaining soil concentrations for the various soil-removal alternatives at these three waste sites.

The results of this analysis support the evaluation of various removal, treatment, and disposal (RTD) alternative cases for the 216-Z-1A Tile Field, the 216-Z-9 Trench, the 216-Z-12 Crib, and their waste groups (see Chapters 6.0 and 7.0 of the main text).

F2.0 Contaminant Distribution

The human-health risk assessment (Appendix A) identified the primary risk drivers in soil to the future subsistence farmer and future well driller at the 216-Z-1A Tile Field and the 216-Z-9 Trench as Am-241 and Pu-239/240. Through other site investigations, Am-241 and Pu-239/240 were also identified as the likely COPCs at the 216-Z-12 Crib (*RHO-ST-44, 216-Z-12 Transuranic Crib Characterization: Operational History and Distribution of Plutonium and Americium*). The distribution of these contaminants with depth at these three waste sites is shown in Figures F-1, F-2, and F-3. Although it is generally true that the shallow depths near the liquid waste release points at these waste sites have higher concentrations of these contaminants, significant concentrations also are found deeper in the vadose zone at the high-salt waste sites (216-Z-1A Tile Field and 216-Z-9 Trench).

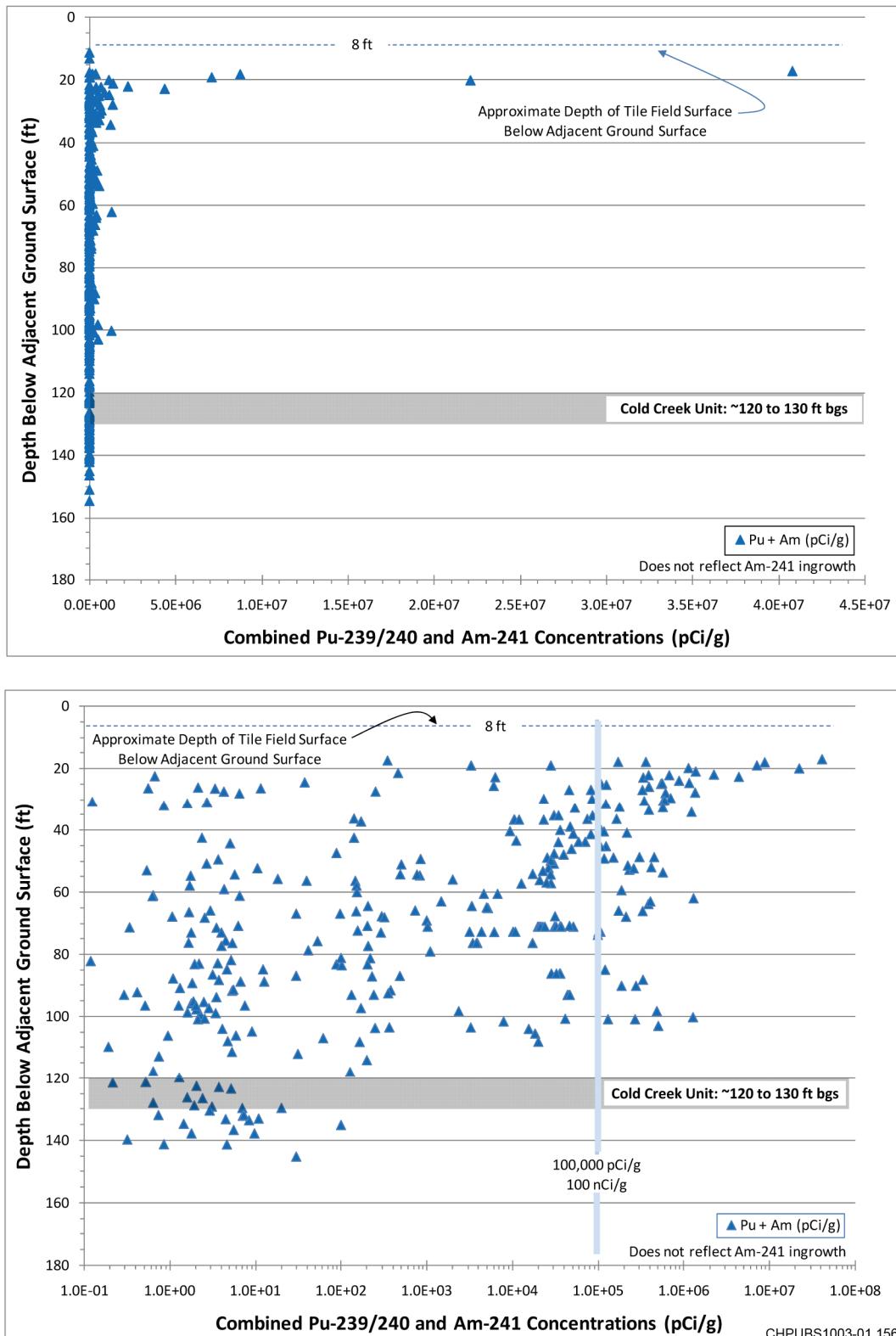


Figure F-1. Distribution of Pu-239/240 and Am-241 (Combined Activities) in Soil Beneath the 216-Z-1A Tile Field (Linear and Log Scales)

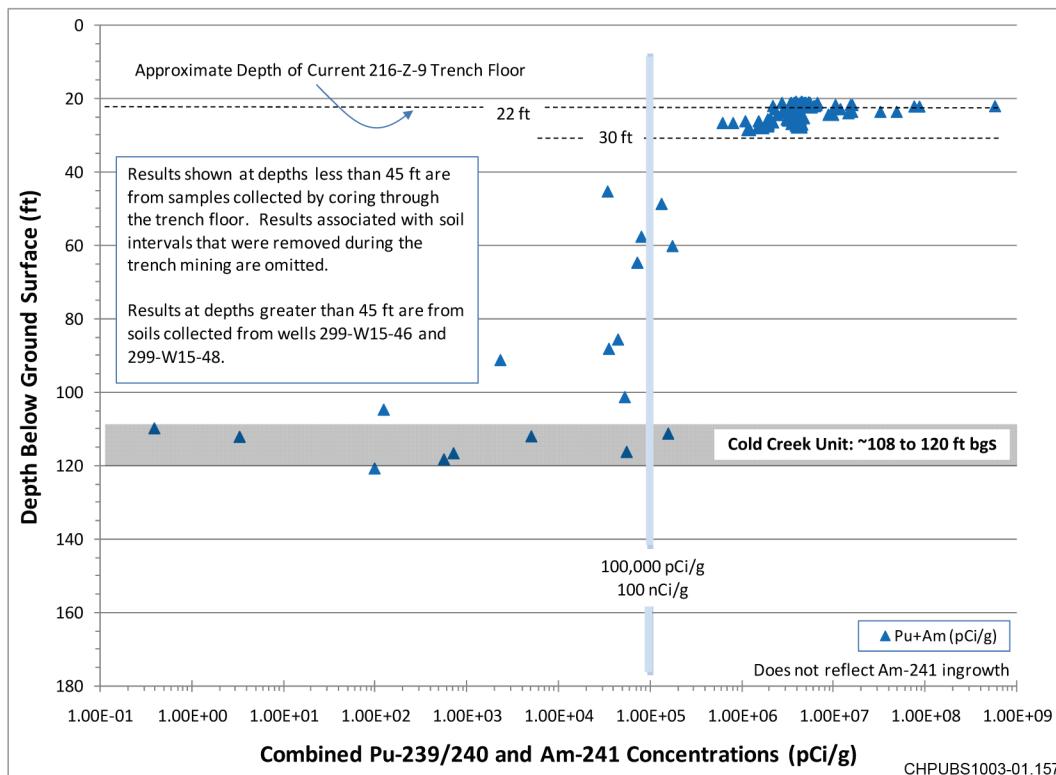
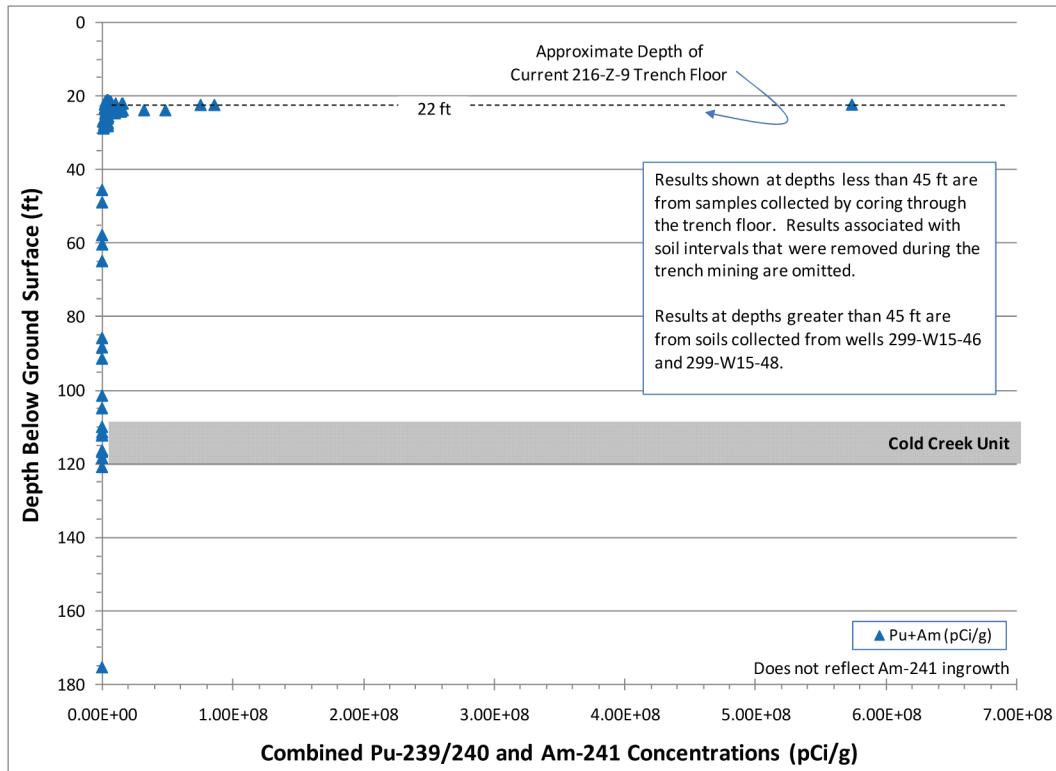


Figure F-2. Distribution of Pu-239/240 and Am-241 (Combined Activities) in Soil Beneath the 216-Z-9 Trench (Linear and Log Scales)

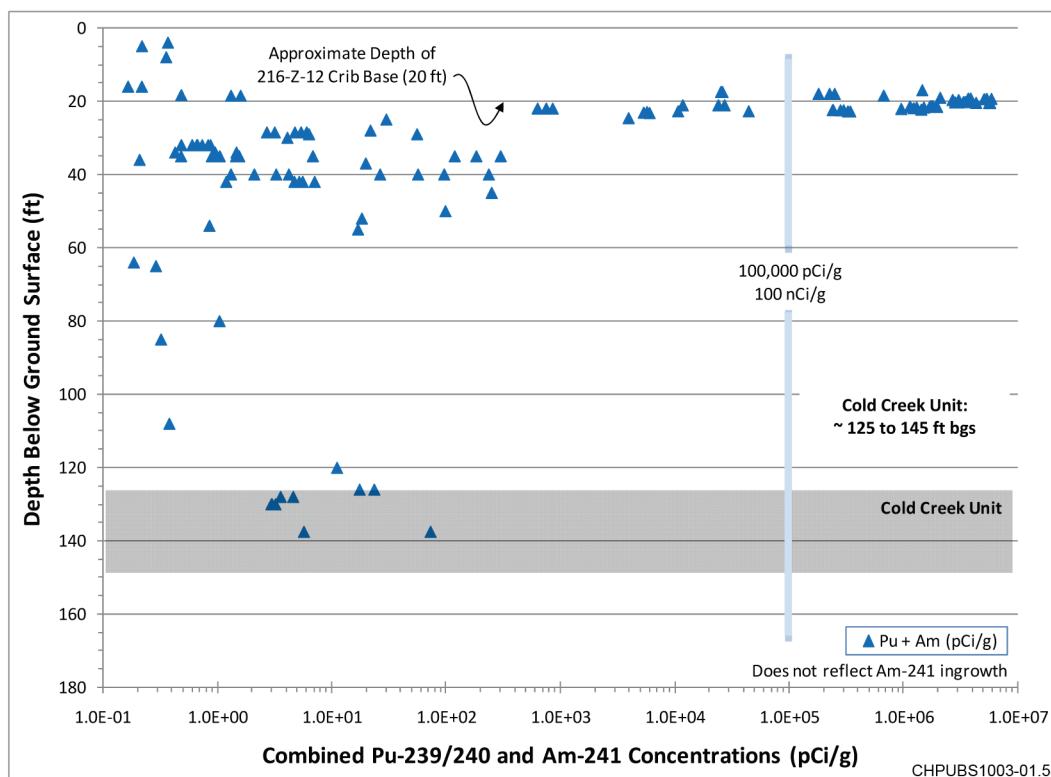
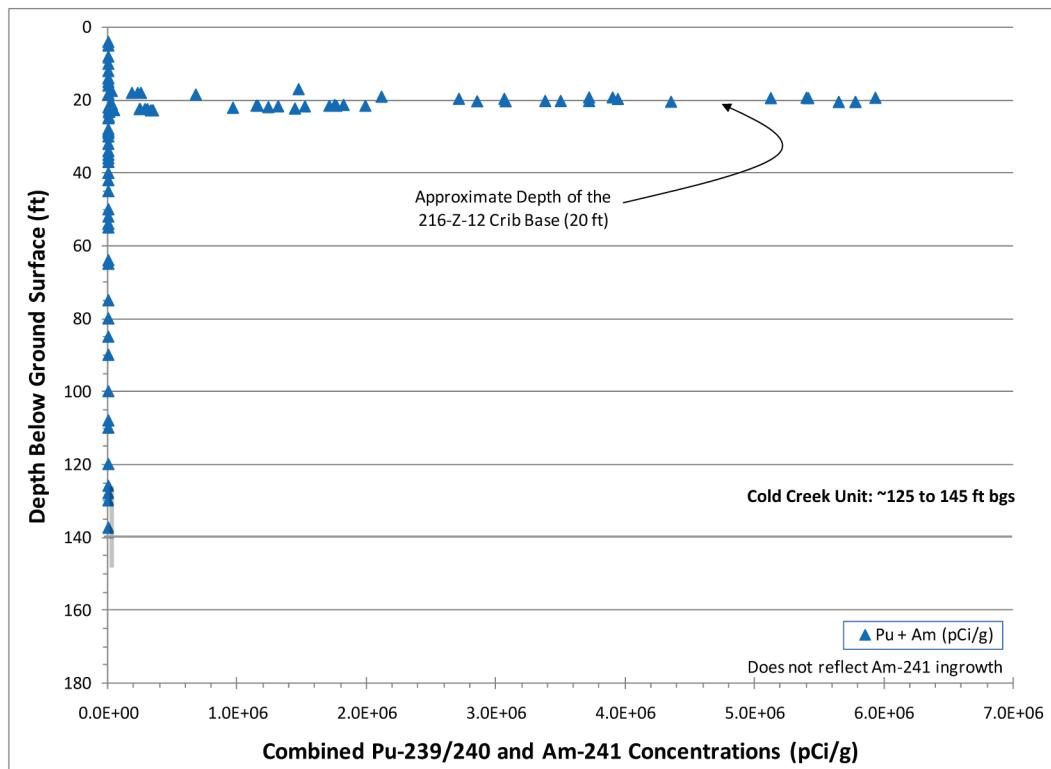


Figure F-3. Distribution of Pu-239/240 and Am-241 (Combined Activities) in Soil Beneath the 216-Z-12 Crib (Linear and Log Scales)

F3.0 Future Well Driller Baseline Risk and Future Risk Reduction Evaluation

In Appendix A (Sections A5.3 and A5.4), the risks were evaluated for a future well driller exposed to contaminants in soil via drill cuttings while engaged in installing a water supply well through the 216-Z-9 Trench and 216-Z-1A Tile Field. Under this scenario 150 years in the future, all knowledge of the site is lost, there is a failure of institutional controls, and the worst case is evaluated for a water well drilled through each waste site. For the radionuclide contaminants of potential concern (COPCs), the risks presented are for 150 years in the future as it is anticipated that institutional controls would be unlikely to fail before that time. However, because of the long half-lives of the principal radionuclide COPCs, the risks at the 216-Z-9 Trench and 216-Z-1A Tile Field do not change significantly between 150 years and 1,000 years in the future.

The exposure routes evaluated for the future well driller were inhalation (including radon), ingestion, and external radiation. At the 216-Z-9 Trench, three nonradionuclide COPCs (cadmium, carbon tetrachloride, and manganese) were evaluated in addition to the radionuclides, and all non-cancer hazards were well below a target hazard index of 1. The baseline risks for future well drillers are presented in Table F-1. Well driller risks did not exceed 10^{-4} at either of these waste sites. The specific baseline risk results are below:

- **216-Z-1A Tile Field:** Cumulative risks were 3×10^{-6} , due to Am-241 (80 percent of total risks), followed by Pu-239 (18 percent of total). Risks are driven by the external radiation pathway for Am-241.
- **216-Z-9 Trench:** Cumulative risks were 2×10^{-5} for the radionuclides, with Pu-239 (46 percent of total), Am-241 (43 percent of total risks), and Pu-240 having risks in excess of 1×10^{-6} . Carbon tetrachloride had the highest risks of the two nonradionuclide carcinogens, with risks of 2×10^{-6} . Ingestion of Pu-239 and external radiation due to Am-241 are the pathways contributing to overall risks.

In summary, the baseline risks for future well drillers at the 216-Z-9 Trench and 216-Z-1A Tile Field did not exceed 10^{-4} at either waste site. Therefore, because the baseline risks for the future well drillers are within acceptable levels with no soil removal at these waste sites, any soil-removal alternatives at these waste sites would further reduce the future risk to the well drillers, but such action is not required by the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) or other potential applicable or relevant and appropriate requirements (ARARs). Although health risks to a future well driller were not calculated for the 216-Z-12 Crib, the risks would be similar to those calculated at the 216-Z-9 Trench and 216-Z-1A Tile Field and would not exceed 10^{-4} , based on the similar concentrations of plutonium and americium found at the three sites.

The future well driller is not considered further in the evaluation presented in this appendix.

Table F-1. Well Driller Baseline Risks from Soil

Radionuclide (Parent and Decay) or Contaminant	Total*	Inhalation	Ingestion	External Radiation	Radon
216-Z-1A Tile Field					
Am-241	3E-06	9E-10	5E-08	2E-06	--
Pu-239	5E-07	9E-09	4E-07	9E-08	--
Pu-240	1E-07	2E-09	1E-07	1E-08	--
Total – 150 years	3E-06	1E-08	6E-07	3E-06	6E-24
216-Z-9 Trench					
Am-241	7E-06	2E-09	1E-07	7E-06	--
Eu-152	1E-10	2E-18	1E-15	1E-10	--
Ni-63	4E-12	2E-15	4E-12	--	
Np-237	7E-08	1E-12	5E-11	7E-08	--
Pu-238	8E-10	2E-11	7E-10	9E-11	--
Pu-239	7E-06	1E-07	6E-06	1E-06	--
Pu-240	2E-06	3E-08	1E-06	2E-07	--
Ra-226	8E-08	2E-13	4E-11	8E-08	--
Ra-228	5E-16	3E-21	1E-18	5E-16	--
Sr-90	5E-12	5E-17	1E-13	5E-12	--
Tc-99	6E-21	7E-25	1E-21	5E-21	--
Th-228	1E-15	1E-20	5E-19	1E-15	--
Th-230	3E-11	2E-13	1E-11	2E-11	--
Radionuclide Total – 150 years	2E-05	2E-07	7E-06	8E-06	3E-11
Cadmium	1E-12	1E-12	--	--	--
Carbon tetrachloride	2E-06	2E-06	1E-09	--	--
Contaminant Total*	2E-06	2E-06	1E-09	--	--

Notes:

*Totals are calculated using unrounded values

-- = indicates incomplete pathway or not applicable

F4.0 Future Subsistence Baseline Risk and Future Risk Reduction Evaluation

In Appendix A (Sections A5.3 and A5.4) the human-health risk assessment found significant baseline health risks for a future residential farming population if they were to be exposed to impacted subsurface soils from the 216-Z-1A Tile Field and the 216-Z-9 Trench. Using the same inputs for the 216-Z-12 Crib as in Appendix A, significant risks are also present at the 216-Z-12 Crib for future subsistence farmer exposures to subsurface soil at that site. The remainder of this appendix evaluates future risk reduction to the subsistence farmer from various soil removal cases at these three waste sites.

F4.1 Selection of Contaminants of Concern

Risk assessment procedures initially select COPCs by screening maximum concentrations of detected contaminants against generic health-protective screening concentrations. Additional considerations also factor into COPC selection, e.g., natural background levels, whether a contaminant is an essential nutrient, chemical toxicity, and the magnitude and frequency of exceedances above screening levels. Once COPCs are selected, the baseline risk assessment performs an in-depth, site-specific analysis to determine whether health risks are potentially present at the site using conservative, health-protective, assumptions. At the end of the risk assessment process, final COPCs are selected. A COPC becomes a final COPC if at least one of the following applies:

- The contaminant exceeds a target health goal
- The contaminant does not exceed a target health goal but contributes a significant percentage to total site risks (i.e., is a concern not necessarily alone, but contributes substantially to the site's cumulative risks)

In addition to the above, a chemical may be included or excluded as a COPC regardless of risk results if fate, transport, toxicity, or other special considerations warrant its inclusion or exclusion; however, the rationale for such an inclusion or exclusion should be presented and approved by the applicable regulatory agencies.

There are two sets of target health goals under CERCLA, determined by different methodologies: one for contaminants where the toxic effect of concern is not cancer, and the other for carcinogens. The selection of COPCs at 216-Z-9 and 216-Z-1A is made on the basis of their exceedances above cancer health goals because, with the exception of carbon tetrachloride, no other contaminants have non-cancer hazards in excess of health goals; however, carbon tetrachloride also has cancer risks exceeding the cancer health goal. The U.S. Environmental Protection Agency's (EPA) target health goal for carcinogens is a cancer risk range of 10^{-6} to 10^{-4} . Risks below 10^{-6} are considered to be acceptable. While EPA's target risk range begins at 10^{-6} , EPA generally does not recommend taking action at a site unless the upper end of the target risk range (i.e., 10^{-4}) is exceeded (Clay, 1991, "Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions," OSWER Directive 9355.0-30). In addition, EPA does not necessarily consider 10^{-4} a discrete line but will allow risks slightly higher than that to remain at a site if justified based on site-specific conditions (EPA 540-R-97-013, *Rules of Thumb for Superfund Remedy Selection*, OSWER 9355.0-69). Therefore, a site-specific risk above 10^{-4} was considered an initial threshold in selecting COPCs for the three waste sites; however, a contaminant's contribution to the overall cumulative risk total and special considerations for nonradionuclides also were considered in final COPC selection. For the 216-Z-12 Crib, which did not go through the full risk assessment evaluation in Appendix A, the only contaminant data were for Am-241, Pu-238, Pu-239, and Pu-240. Three of these four radionuclides were evaluated as COPCs as described in Section F4.1.3. Table F-2 presents the contaminants that exceeded 10^{-4} for the subsistence farmer scenario at all three waste sites, and selection of final COPCs is detailed below.

F4.1.1 216-Z-1A Tile Field Contaminants of Potential Concern

As shown in Table F-2, Am-241, Pu-239, and Pu-240 are selected as final COPCs for this waste site. These three contaminants were the only ones at this site with risks exceeding 10^{-4} and they make up 99.9 percent of the total site risks. The risk percentages were calculated including one additional COPC evaluated at the site (Np-237) and an additional nine daughter products evaluated in the baseline risk assessment (daughter products are automatically included in the risk modeling program used to estimate radionuclide risks).

F4.1.2 216-Z-9 Trench Contaminants of Potential Concern

Americium-241, Pu-239, and Pu-240 also are selected as final COPCs at the 216-Z-9 Trench (see Table F-2). These three contaminants make up 99.7 percent of the total radionuclide risks including all radionuclide COPCs and daughter products evaluated at this site in the baseline risk assessment (10 additional radionuclide COPCs plus 10 daughter products were evaluated). Two other radionuclides, Np-237 and Ra-226, had total risks of 2×10^{-4} each but were not selected as COPCs because (1) their risks essentially were equal to the upper bound target health goal (and this goal is not a discrete line), and (2) their combined risks contribute only 0.2 percent of the cumulative risks at this site. One nonradionuclide COPC, carbon tetrachloride, had risks exceeding 10^{-4} due to ingestion of home-grown produce. However, carbon tetrachloride is not considered a final COPC in soil because the risks and hazards for this contaminant were estimated using current concentrations, and in 150 years (the earliest assumed date at which residential exposure could occur), carbon tetrachloride concentrations in soil are likely to be considerably lower due to weathering and degradation processes in the environment. Therefore, concentrations (and consequently health risks) are expected to be lower than present values, although the reduction in concentration was not quantified. In contrast, radionuclide concentrations 150 years in the future for Am-241, Pu-239, and Pu-240 will not be significantly lower than today due to the long half-lives of these radionuclides.

F4.1.3 216-Z-12 Crib Contaminants of Concern

Americium-241, Pu-239, and Pu-240 were initially selected as COPCs at the 216-Z-12 Crib, based on the frequency and magnitude of exceedances over their risk-based screening levels. Americium-241, Pu-239, and Pu-240 are all also final COPCs at this site because their risks exceed 10^{-4} (see Table F-2) and each radionuclide makes a significant contribution to cumulative site risks. Although Pu-238 was detected at this site at concentrations exceeding its risk-based screening level of 2.9 pCi/g, the 95 percent upper confidence limit (95 percent UCL) of its mean concentration of 1.08 pCi/g is below the risk-based screening level. Therefore, Pu-238 was not identified as a COPC at the 216-Z-12 Crib and thus would not be a final COPC.

Table F-2. Future Subsistence Farmer Baseline Risks for Contaminants with Risks Greater than 10^{-4}

Radionuclide or Contaminant	Percentage of Total Risks Including all COPCs	Total Risk	Direct Exposure Pathways			Food Chain Pathway Produce*
			Inhalation	Ingestion	External Radiation	
216-Z-1A Tile Field						
Am-241	16%	2E-03	4E-07	4E-05	1E-03	3E-04
Pu-239	69%	8E-03	1E-05	9E-04	2E-04	7E-03

Table F-2. Future Subsistence Farmer Baseline Risks for Contaminants with Risks Greater than 10⁻⁴

Radionuclide or Contaminant	Percentage of Total Risks Including all COPCs	Total Risk	Direct Exposure Pathways			Food Chain Pathway Produce*
			Inhalation	Ingestion	External Radiation	
Pu-240	15%	2E-03	3E-06	2E-04	2E-05	2E-03
Radionuclide Total		1E-02	1E-05	1E-03	1E-03	8E-03
216-Z-9 Trench						
Am-241	3.5%	5E-03	1E-06	1E-04	4E-03	8E-04
Np-237	0.1%	2E-04	1E-09	1E-07	2E-04	1E-05
Pu-239	79%	1E-01	2E-04	1E-02	3E-03	9E-02
Pu-240	17%	2E-02	4E-05	3E-03	2E-04	2E-02
Ra-226	0.1%	2E-04	1E-10	6E-08	2E-04	2E-05
Radionuclide Total		1E-01	2E-04	2E-02	1E-02	1E-01
Carbon tetrachloride		1E-03	5E-05	3E-06	--	1E-03
216-Z-12 Crib						
Am-241	33%	1E-03	4E-07	3E-05	1E-03	2E-04
Pu-239	55%	2E-03	4E-06	3E-04	6E-05	2E-03
Pu-240	12%	5E-04	8E-07	6E-05	5E-06	5E-04
Radionuclide Total		4E-03	5E-06	4E-04	1E-03	3E-03

Notes:

Shading indicates the contaminant is a contaminant of concern.

* Produce grown in impacted soil is the only food chain pathway evaluated for soil. For beef cattle and dairy cattle, their exposures are due to drinking impacted water and foraging on plants irrigated with impacted water; thus, risk from ingesting beef cattle and dairy cattle are only due to exposures to contaminants in groundwater. Impacted soil is assumed to be limited to the garden area of the home.

-- = indicates incomplete pathway or not applicable

COPC = contaminant of potential concern

F4.2 Exposure Point Concentrations

To calculate a cancer risk, an estimate must be made of the radiological concentration to which an individual may be exposed. According to EPA guidance (OSWER Publication 9285.7-081, *Supplemental Guidance to RAGS: Calculating the Concentration Term*), the concentration term at the exposure point (the exposure-point concentration [EPC]) should be an estimate of the average concentration to which an individual would be exposed over a significant part of a lifetime. Because of the uncertainty associated with estimating the true average concentration at a site, EPA generally recommends the use of the 95 percent UCL of the arithmetic mean as the appropriate estimate of the average site concentration for a reasonable maximum exposure scenario (OSWER Directive 9285.6-03, *Risk Assessment Guidance for*

Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance “Standard Default Exposure Factors” Interim Final). At the 95 percent UCL, the probability of underestimating the true mean is less than 5 percent. The 95 percent UCL can address the uncertainties surrounding a distribution average due to limited sampling data. Calculation of the 95 percent UCL in the baseline risk assessment and for the calculations in Section F4.2.2 was accomplished using EPA’s ProUCL software (EPA, 2004, *ProUCL Version 3.00.02*)¹.

The EPCs used to calculate the baseline future subsistence risks shown in Table F-2 included all the subsurface soil data in the vadose zone at each waste site, modified to represent subsistence farmer exposure conditions as described in Section F4.2.2. To assess the potential risk reduction if certain depth intervals of impacted soil were removed from each waste site, EPCs must be recalculated after removing the sampling point data from a specific depth interval. Once EPCs have been recalculated, risks can be calculated for the new soil concentrations to which subsistence farmers would be exposed.

For the 216-Z-1A Tile Field, revised EPCs were calculated under seven removal scenarios (from current ground surface):

- Removal of 0 to 6.1 m (20 ft) of soil
- Removal of 0 to 12.2 m (40 ft) of soil
- Removal of 0 to 18.3 m (60 ft) of soil
- Removal of 0 to 22.9 m (75 ft) of soil
- Removal of 0 to 24.4 m (80 ft) of soil
- Removal of 0 to 27.4 m (90 ft) of soil
- Removal of 0 to 30 m (95 ft) of soil

For the 216-Z-9 Trench, revised EPCs were calculated for one removal scenario: removal of soil located 0.36 to 2.7 m (1.2 to 9 ft) directly below the bottom of the trench.

For the 216-Z-12 Crib, revised EPCs were calculated under three removal scenarios (from current ground surface):

- Removal of 0 to 6.1 m (20 ft) of soil
- Removal of 0 to 7.6 m (25 ft) of soil
- Removal of 0 to 9.1 m (30 ft) of soil

F4.2.1 Estimation of Americium-241 Concentrations

As noted above, the development of subsistence farmer EPCs for the baseline risk assessment started with the available soil data in the vadose zone beneath each site. However, the available historical Am-241 data underestimate the maximum future americium concentrations. Americium-241 is the daughter product of Pu-241, which was produced as part of the plutonium-production processes, and there are no data for Pu-241 because of the difficulties with analyzing for this isotope of plutonium. Plutonium-241 has a relatively short half-life of 14.5 years. The production of plutonium (including Pu-241) started in 1944 at the Hanford Site. The final waste disposal to the 200-PW-1 and -6 OU waste sites varied and, therefore, some sites are further along the Am-241 in-growth curve than others. Because the Am-241 data at the 216-Z-1A Tile Field, 216-Z-9 Trench, and 216-Z-12 Crib came from past laboratory analyses

¹ After the baseline risk assessment was completed, EPA released a newer version of its ProUCL software. The calculations for 216-Z-9 and 216-Z-1A in this Appendix were accomplished using the older software (v.3.00.02) to provide consistency with the baseline risk assessment results. Because the 216-Z-12 Crib was not included in the original evaluation, 95% UCLs for the 216-Z-12 Crib were calculated using EPA 2007, ProUCL Version 4.00.02.

(1979, 1963, 1973, and 1980, respectively), Am-241 concentrations in the available data sets likely do not represent the maximum in-growth concentrations of this radionuclide. Therefore, maximum concentrations of Am-241 were estimated using the disposal date information for each waste site, the date of the available Am-241 laboratory data, and the RESidual RADioactivity (RESRAD) dose model, which can estimate radiological concentrations in the future taking into consideration radionuclide decay and in-growth.

Maximum Am-241 concentrations are estimated below:

- Liquid waste disposal at the 216-Z-1A Tile Field occurred from 1964 to 1969, at the 216-Z-9 Trench from 1955 to 1962, and at the 216-Z-12 Crib from 1959 to 1973. The “0” year in the RESRAD model therefore was estimated to be 1967 for the 216-Z-1A Tile Field, 1960 for the 216-Z-9 Trench, and 1966 for the 216-Z-12 Crib.
- Site-specific information on the vadose zone and the contaminant distribution for each site was entered into RESRAD (see Chapters 2.0 and 3.0 of the main text).
- The known Am-241 concentration for each site was the 95 percent UCL of the available historical data. This was 1979 for the 216-Z-1A Tile Field (year 12 in RESRAD), 1973 for the 216-Z-9 Trench (year 13 in RESRAD), and 1980 for the 216-Z-12 Crib (year 14 in RESRAD).
- Plutonium-241 concentrations at year 0 were entered into RESRAD until the Am-241 concentrations at the applicable year matched the existing data.

The resulting Am-241 in-growth curves were graphed for each site and are presented in Figures F-4, F-5, and F-6 for the 216-Z-1A Tile Field, the 216-Z-9 Trench, and the 216-Z-12 Crib, respectively. At all three sites, it appears that the maximum Am-241 concentration would occur around 60+ years from year 0. Therefore, current Am-241 concentrations are likely 20 to 25 years from their maximum values. Because year 2005 concentrations are aged to represent 150 years in the future (the earliest subsistence farmer exposures; see Section 3.2 of the main text), use of the maximum Am-241 concentration as the current concentration only slightly overestimates Am-241 concentrations in the year 2150. For the 216-Z-1A Tile Field, the year 2005 concentrations are 93 percent of their maximum concentration (occurring approximately 73 years from time 0, or year 2040 if time 0 is 1967). For the 216-Z-9 Trench, current year concentrations are 96 percent of their maximum concentration, which occurs around 63 years from time 0, or year 2023 if time 0 is 1960. At the 216-Z-12 Crib, current concentrations are 95 percent of their maximum concentration, which occurs around 64 years from time 0, or year 2030 if time 0 is 1966. Because this analysis is meant to be a reasonable approximation of a maximum americium concentration, an exhaustive analysis over exactly what year should be year 0, and the possible differing amounts of Pu-241 that might have been disposed each year of operation, has not been performed. The maximum concentrations estimated as described above were used as reasonably health-protective, given the lack of Pu-241 data and the uncertainties in the estimation process. This slight potential overestimation does not have a significant effect on estimates of health risk.

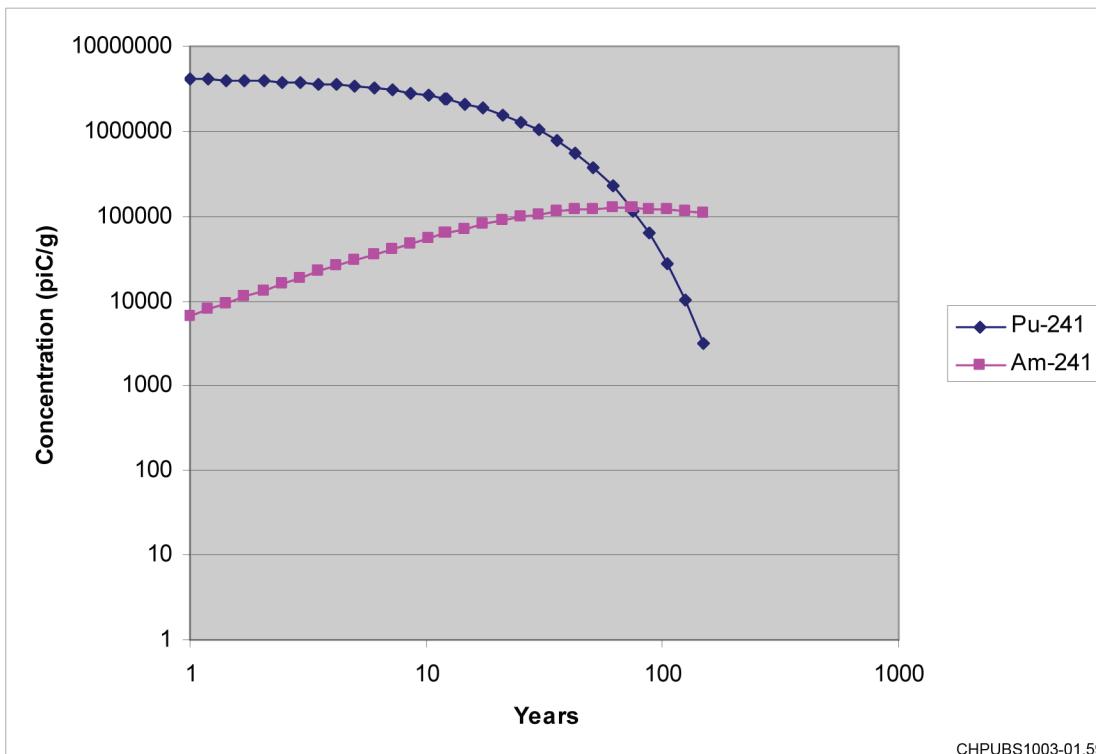


Figure F-4. In-Growth of Americium-241 at the 216-Z-1A Tile Field

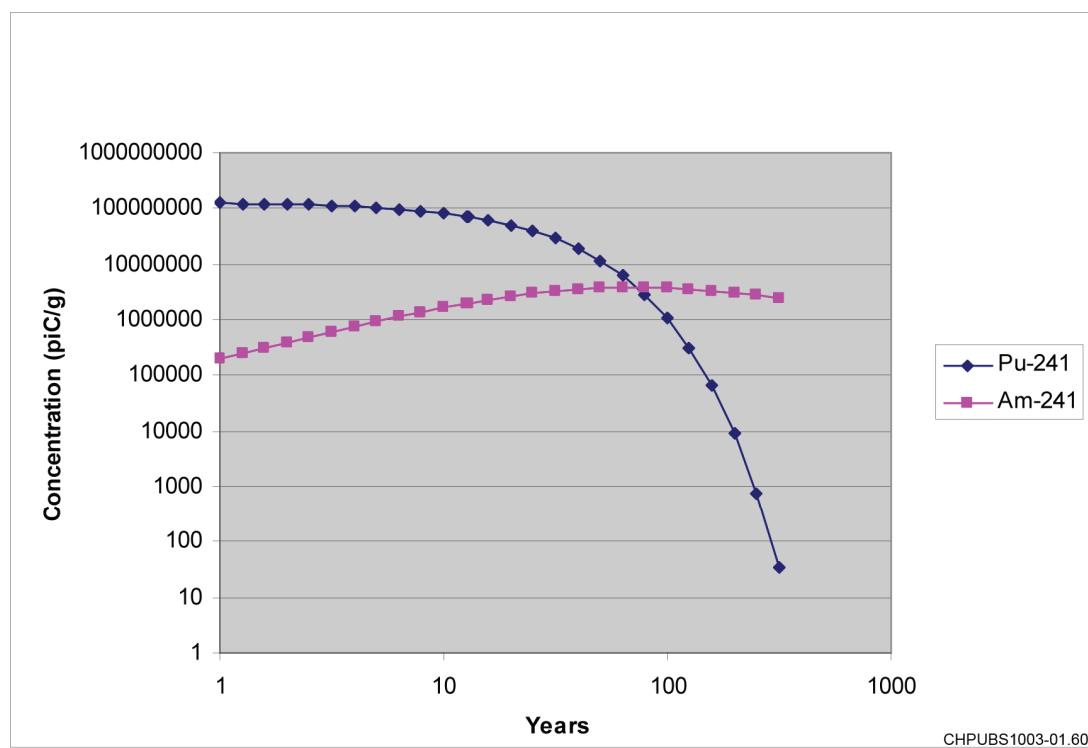
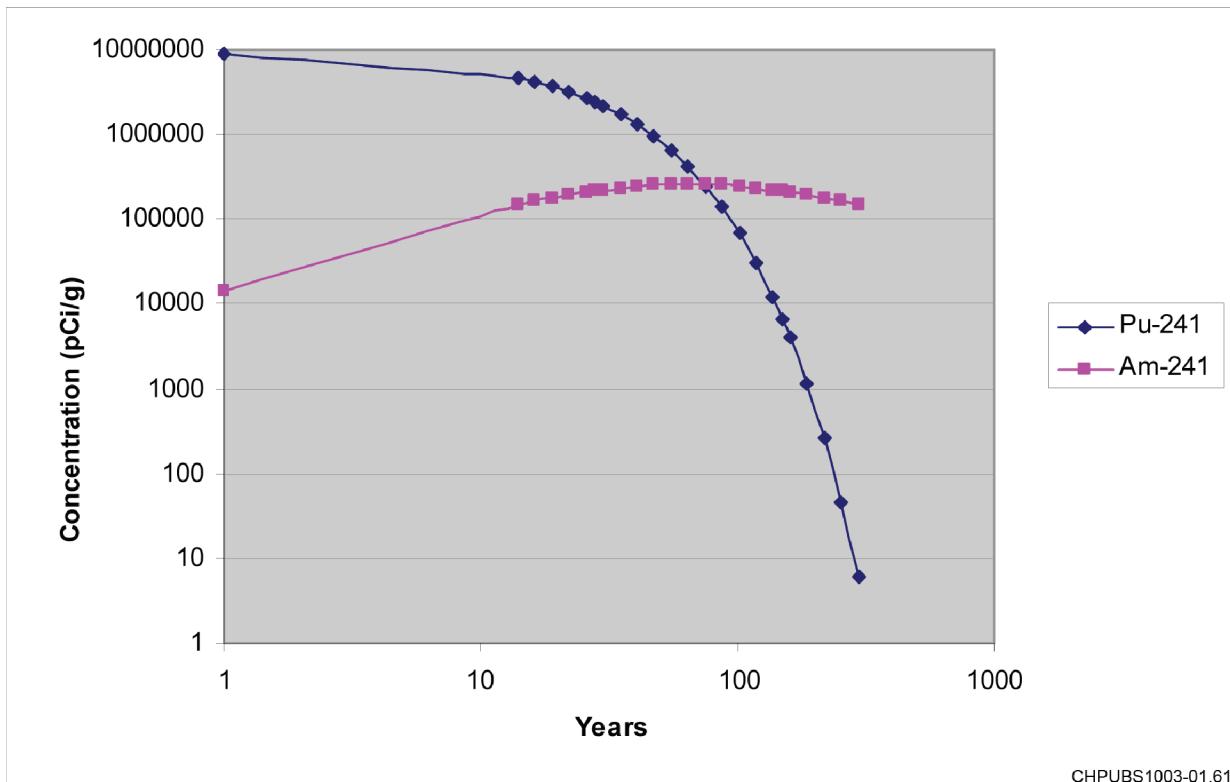


Figure F-5. In-Growth of Americium-241 at the 216-Z-9 Trench

**Figure F-6. In-Growth of Americium-241 at the 216-Z-12 Crib**

At the 216-Z-9 Trench where there is current (2005 to 2006) as well as historical data for Am-241, the current Am-241 data were not adjusted because it is sufficiently close to its maximum concentration. The maximum predicted values for the 216-Z-1A Tile Field, the maximum predicted values for the 216-Z-12 Crib, and the maximum predicted values from the 1973 measurements combined with the 2005 to 2006 data at the 216-Z-9 Trench were used to estimate soil concentrations and subsequent health risks in the sections that follow.

F4.2.2 Subsistence Farmer Exposure Point Concentration Calculation Methodology

The following terms are used in this section and are provided here with shortened definitions for ease of reader comprehension. For more detailed definitions, see Table F-6.

Ccut	=	Contaminant concentration in cuttings
Cgarden	=	Contaminant concentration in garden soil
Cwaste	=	Contaminant concentration at waste site
Lwaste	=	Thickness of the waste (m)
Lwell	=	Depth of well from surface to groundwater
Vcut	=	Volume of cuttings (m^3)
Vgarden	=	Volume of garden soil ($15 m^3$)

For residents to come into contact with contamination in soil, the impacted soil at depth at the waste sites must be brought to the surface. As described in the baseline risk assessment, this scenario would only occur if all knowledge of the site is lost as are any markers or indicators that could be placed on the site, and this is not considered to be possible in this assessment until at least the year 2150. At this time, it is assumed that the likeliest way for subsurface material to be brought to the surface would be through drilling a well and the drill cuttings being spread in the area of a residential home and vegetable garden. Then, through daily activities, residents potentially could be exposed to surface soil through ingestion, inhalation of fugitive dust and vapors, external radiation, and ingestion of home-grown produce grown in impacted soils.

The majority of the baseline risk assessment assumptions that were required to estimate concentrations of contamination brought to the surface as well cuttings were developed in HNF-SD-WM-TI-707, 2004, *Exposure Scenarios and Unit Dose Factors for the Hanford Tank Waste Performance Assessment*. For details of formula derivation and assumption rationales, refer to HNF-SD-WM-TI-707 and the baseline risk assessment (Appendix A).

Calculation of a soil concentration in a home garden 150 years in the future was done in the baseline risk assessment and in this appendix according to the following steps:

1. Estimate the current soil concentration in the vadose zone using the available data. This concentration is referred to as Cwaste and the baseline Cwaste concentrations for the final COPCs are shown in Table F-3. The soil sample locations for each waste site that were used in the calculations are provided in Figures F-7 through F-9. Because a well could be drilled anywhere within each of the waste areas, the entire vadose zone data set for each area was used in the 95 percent UCL calculation to represent a high-end estimate of the average contaminant concentration in the vadose zone. For the 95 percent UCL calculations at the 216-Z-9 Trench, certain samples were weighted differently due to uneven sampling within the vadose zone (i.e., some depth intervals had much more data than others; see the footnote in Table F-3 and Figure F-7).

Table F-3. Baseline Risk Assessment Vadose Zone Concentrations (Cwaste)

Site Name	Contaminant Name	Cwaste (pCi/g)	Distribution	Statistical Basis of Cwaste 95UCL Recommended by ProUCL	No. of Samples
216-Z-1A Tile Field	Americium-241	122,528	Non-parametric	95% Chebyshev (Mean, Sd) UCL	458
	Plutonium-239/240	698,678	Non-parametric	95% Chebyshev (Mean, Sd) UCL	423
216-Z-9 Trench*	Americium-241	300,556	Gamma	Adjusted Gamma UCL	41
	Plutonium-239/240	8,903,844	Non-parametric	99% Chebyshev (Mean, Sd) UCL	25
216-Z-12 Crib	Americium-241	251,885	Non-parametric	97.5% KM (Chebyshev) UCL	217
	Plutonium-239/240	499,102	Non-parametric	97.5% KM (Chebyshev) UCL	228

Notes:

*At the 216-Z-9 Trench, there is a preponderance of data in the shallowest layer (ARH-2915), and these data also represent the highest concentrations. Therefore, to reasonably estimate vadose-zone concentrations, the following additional steps were used in the Cwaste exposure point concentration calculations at the 216-Z-9 Trench:

(i) Because the sampling was biased toward the shallower depth in holes A, B, C, D, G, and H, whereas in wells 299-W15-46 and 299-W15-48, samples were collected in relatively even depth intervals at deeper depths, less "weight" must be given to each individual data point collected from the lettered "holes" (see Figure F-7).

(ii) To "reduce" the effect of data points collected from the "holes," the average of data collected in each "hole"

must first be taken into account and this average value was used as a single data point in calculating the 95% UCL.

- (iii) No averaging is needed for wells 299-W15-46 and 299-W15-48 because the depths are evenly spread out.
- (iv) Accordingly, the number of data points entered into the 95% UCL calculation is reduced, but the sample size is still adequate. The biased high concentrations from the "holes" are reduced in their importance.
- (v) Because more "weight" is not given to the data collected from deeper depths (greater than 36.6 m [120 ft]) where the concentrations are much lower even though there is a larger volume of cuttings from deeper depths, 95% UCLs are still likely overestimates of the concentrations in Cwaste.

ARH-2915, *Nuclear Reactivity Evaluations of 216-Z-9 Enclosed Trench*.

2. Enter the current calculated waste site soil concentrations (Cwaste) for radionuclides into RESRAD, where concentrations 150 years in the future are calculated taking into consideration radionuclide decay and in-growth. Future waste site soil (Cwaste) concentrations used in the baseline risk assessment are shown in Table F-4.

Table F-4. Baseline Exposure-Point Concentrations for Subsistence Farmer

Final COPC	Cwaste 150 Years in the Future	Ccutting 150 Years in the Future	Subsistence Farmer EPC Cgarden 150 Years in the Future	Units
216-Z-1A Tile Field				
Americium-241	89,640	29,037	10,609	pCi/g
Plutonium-239*	566,400	183,471	67,035	pCi/g
Plutonium-240*	127,300	41,236	15,066	pCi/g
216-Z-9 Trench				
Americium-241	221,000	80,156	28,152	pCi/g
Plutonium-239*	7,264,000	2,634,617	925,331	pCi/g
Plutonium-240*	1,574,000	570,882	200,505	pCi/g
216-Z-12 Crib				
Americium-241	167,400	23,206	8,479	pCi/g
Plutonium-239*	404,200	56,033	20,473	pCi/g
Plutonium-240*	90,810	12,589	4,600	pCi/g

Notes:

*Plutonium-239 and Pu-240 were analyzed together. Individual radionuclide concentrations were obtained assuming a ratio of 4.4:1 (Pu-239:Pu-240). The basis for this ratio is below:

- (vi) In weapons-grade plutonium, 94.2% of the weight of Pu-239/240 mixture is Pu-239 and 5.8% of the weight is Pu-240. Therefore, 1 g of weapons-grade Pu-239/240 contains 0.942 g of Pu-239 and 0.058 g of Pu-240
- (vii) The specific activity of Pu-239 is 61.5 mCi/g and the specific activity of Pu-240 is 227 mCi/g
- (viii) Therefore, the activity of Pu-239 in 1 g of weapons-grade Pu-239/Pu-240 is $61.5 \text{ mCi/g} \times 0.942 \text{ g} = 57.9 \text{ mCi}$ and
- (ix) The activity of Pu-240 in 1 g of weapons-grade Pu-239/Pu-240 is $227 \text{ mCi/g} \times 0.058 \text{ g} = 13.2 \text{ mCi}$.
- (x) Therefore, the relative activity of Pu-239 to Pu-240 in a weapons-grade mixture of Pu-239/240 = 4.4:1 (4.4 times as much Pu-239 as Pu-240 in units of activity).

3. Estimate the concentration in the drill cuttings (C_{cut}) from the concentration in the waste site soils (C_{waste}) according to the following formula:

$$C_{cut} = C_{waste} \times (L_{waste}/L_{well}) \quad \text{EQ-F1}$$

where:

L_{well} = the length (depth) of the groundwater well (the distance to the water table from ground surface plus 15.2 m (50 ft), the assumed depth for completing a shallow irrigation well)

L_{waste} = the thickness of the contaminated soil (determined by where concentrations exceed health-based screening criteria)

4. Estimate the concentration in the garden soil (C_{garden}) from the concentration in the drill cuttings (C_{cut}) according to the following formula:

$$C_{garden} = C_{cut} \times (V_{cut}/V_{garden}) \quad \text{EQ-F2}$$

where:

V_{cut} = the volume of soil brought to the surface as cuttings assuming a 26.7-cm (10.5-in.)-diameter well is drilled (small-scale irrigation well, larger than a well used only for drinking water 16.5 cm [6.5 in.] and smaller than a commercial irrigation well 40.6 cm [16 in.]).

V_{garden} = the volume of soil in the garden assuming drill cuttings would be spread over a 100-m² (1,076-ft²) area and the spreading depth of contaminated soil is 15 cm (6 in.), the default shallowest tilling depth.

For all calculations, it is assumed that the average density in the soil is the same as the density in the waste (a reasonable assumption for contamination in soil via infiltration of liquid wastes).

The concentration in the cuttings (C_{cut}) and the concentration in the garden soil (C_{garden}) values used in the baseline risk assessment are shown in Table F-4. Table F-5 presents values for the well depth (L_{well}), thickness of contaminated soil at the waste site (L_{waste}), and the volume of cuttings (V_{cut}) for the 216-Z-1A Tile Field, the 216-Z-9 Trench, and the 216-Z-12 Crib for the removal scenarios; the different removal options affect the L_{waste} value only. The waste site soil concentrations (C_{waste}), the concentration in the cuttings (C_{cut}), and the garden soil (C_{garden}) concentrations for the removal scenarios (seven at the 216-Z-1A Tile Field, one at the 216-Z-9 Trench, and three at the 216-Z-12 Crib) are presented in Table F-6. Table F-7 presents the RESRAD site-specific parameters that were used with the waste site soil (C_{waste}) concentrations for each removal scenario to estimate the “aged” C_{waste} concentrations.

Table F-5. Summary of Parameters Used to Calculate Exposure-Point Concentrations

V_{cut}^a (m ³)	Ratio L_{waste} to L_{well}	L_{waste} -Thickness of Waste (m)	L_{well} -Depth of Well (m)	Depth to Groundwater (m)
216-Z-1A Tile Field^b				
Removal of 6.1 m (20 ft)				
5.480579867	0.3	23.74	87	71
Removal of 12.2 m (40 ft)				

Table F-5. Summary of Parameters Used to Calculate Exposure-Point Concentrations

Vcut ^a (m ³)	Ratio Lwaste to Lwell	Lwaste–Thickness of Waste (m)	Lwell–Depth of Well (m)	Depth to Groundwater (m)
5.480579867	0.2	17.64	87	71
Removal of 18.3 m (60 ft)				
5.480579867	0.1	11.54	87	71
Removal of 22.9 m (75 ft)				
5.480579867	0.08	6.98	87	71
Removal of 24.4 m (80 ft)				
5.480579867	0.06	5.46	87	71
Removal of 27.4 m (90 ft)				
5.480579867	0.03	2.41	87	71
Removal of 28.9 m (95 ft)				
5.480579867	0.01	0.88	87	71
216-Z-9 Trench				
Removal of 2.7 m (9 ft)				
5.268303886	0.3	27.44	83	68
216-Z-12 Crib^c				
Removal of 6.1 m (20 ft)				
5.480579867	0.12	10.78	87	71
Removal of 7.6 m (25 ft)				
5.480579867	0.11	9.58	87	71
Removal of 9.1 m (30 ft)				
5.480579867	0.09	7.78	87	71

Notes:

- a. Vcut = $\pi \times r^2 \times h \times (D_{initial}/D_{final})$
- b. All removal depths include an assumption of a 1.8 m (6 ft) clean cover before buried waste is reached
- c. All removal depths include an assumption of a 4.88 m (16 ft) clean cover before buried waste is reached

HNF-SD-WM-TI-707, *Exposure Scenarios and Unit Factors for the Hanford Tank Waste Performance Assessment*.

Dfinal = density of soil cuttings on surface (1.5 kg/L; HNF-SD-WM-TI-707)

Dinitial = density of undisturbed soil (1.7 kg/L; HNF-SD-WM-TI-707)

h = Lwell – depth of the well from surface to groundwater, plus 15.24 m (50 ft)

pi = 3.14159

r = radius of 26.67 cm (10.5-in.) well

Vcut = volume of cuttings

Table F-6. Removal Options Exposure-Point Concentrations for the Subsistence Farmer

Contaminant Name	Cwaste (pCi/g)	Distribution	Statistical Basis of Cwaste 95UCL Recommended by PROUCL	Number of Samples	Cwaste 150 Years in the Future (pCi/g)	Ccut ^a 150 Years in the Future (pCi/g)	Subsistence Farmer EPC Cgarden ^b 150 Years in the Future (pCi/g)
216-Z-1A Tile Field							
Removal of 6.1 m (20 ft)							
Americium-241	67,281	Non-parametric	95% Chebyshev	417	48,240	12,227	4,467
Plutonium-239/240	53,258	Non-parametric	95% Chebyshev	390	--	--	--
Plutonium-239 ^c	43,396	--	--	--	43,170	10,942	3,998
Plutonium-240 ^c	9,863	--	--	--	9,698	2,458	898
Removal of 12.2 m (40 ft)							
Americium-241	65,604	Non-parametric	95% Chebyshev	341	45,410	8,315	3,038
Plutonium-239/240	32,358	Non-parametric	95% Chebyshev	323	--	--	--
Plutonium-239 ^c	26,366	--	--	--	26,220	4,801	1,754
Plutonium-240 ^c	5,992	--	--	--	5,890	1,078	394
Removal of 18.3 m (60 ft)							
Americium-241	53,816	Non-parametric	95% Chebyshev	262	34,400	3,875	1,416
Plutonium-239/240	18,489	Non-parametric	95% Chebyshev	259	--	--	--
Plutonium-239 ^c	15,065	--	--	--	14,970	1,686	616
Plutonium-240 ^c	3,424	--	--	--	3,363	379	138
Removal of 22.9 m (75 ft)							
Americium-241	64,603	Non-parametric	95% Chebyshev	202	38,030	3,051	1,120
Plutonium-239/240	21,946	Non-parametric	95% Chebyshev	194	--	--	--
Plutonium-239 ^c	17,882	--	--	--	17,750	1,424	523
Plutonium-240 ^c	4,064	--	--	--	3,988	320	117
Removal of 24.4 m (80 ft)							
Americium-241	69,837	Non-parametric	95% Chebyshev	183	37,930	2,380	874

Table F-6. Removal Options Exposure-Point Concentrations for the Subsistence Farmer

Contaminant Name	Cwaste (pCi/g)	Distribution	Statistical Basis of Cwaste 95UCL Recommended by PROUCL	Number of Samples	Cwaste 150 Years in the Future (pCi/g)	Ccut ^a 150 Years in the Future (pCi/g)	Subsistence Farmer EPC Cgarden ^b 150 Years in the Future (pCi/g)
Plutonium-239/240	23,971	Non-parametric	95% Chebyshev	176	--	--	--
Plutonium-239 ^c	19,532	--	--	--	19,680	1,216	447
Plutonium-240 ^c	4,439	--	--	--	4,353	273	100
Removal of 27.4 m (90 ft)							
Americium-241	77,542	Non-parametric	95% Chebyshev	143	26,380	731	268
Plutonium-239/240	27,523	Non-parametric	95% Chebyshev	139	--	--	--
Plutonium-239 ^c	22,426	--	--	--	22,140	613	225
Plutonium-240 ^c	5,097	--	--	--	4,975	138	51
Removal of 28.9 m (95 ft)							
Americium-241	20,548	Non-parametric	95% Chebyshev	122	1,629	16	6
Plutonium-239/240	10,831	Non-parametric	95% Chebyshev	119	--	--	--
Plutonium-239 ^c	8,825	--	--	--	8,587	87	32
Plutonium-240 ^c	2,006	--	--	--	1,929	20	6
216-Z-9 Trench							
Removal of 2.7 m (9 ft)							
Americium-241	170,059	Non-parametric	95% Chebyshev	40	124,200	40,957	14,385
Plutonium-239/240	80,375	Gamma	Adjusted Gamma UCL	24	--	--	--
Plutonium-239 ^c	65,491	--	--	--	65,160	21,488	7,547
Plutonium-240 ^c	14,884	--	--	--	14,640	4,828	1,696
216-Z-12 Crib							
Removal of 6.1 m (20 ft)							
Americium-241	220,937	Non-parametric	97.5%KM (Chebyshev)	174	144,000	17,933	6,552
Plutonium-239/240	370,638	Gamma	97.5%KM (Chebyshev)	184	--	--	--
Plutonium-239 ^c	302,001	--	--	--	300,100	37372	13,655

Table F-6. Removal Options Exposure-Point Concentrations for the Subsistence Farmer

Contaminant Name	Cwaste (pCi/g)	Distribution	Statistical Basis of Cwaste 95UCL Recommended by PROUCL	Number of Samples	Cwaste 150 Years in the Future (pCi/g)	Ccut ^a 150 Years in the Future (pCi/g)	Subsistence Farmer EPC Cgarden ^b 150 Years in the Future (pCi/g)
Plutonium-240 ^c	68,637	--	--	--	67,430	8397	3,068
Removal of 7.3 m (25 ft)							
Americium-241	19.8	Non-parametric	97.5%KM (Chebyshev)	140	13	1.4	0.5
Plutonium-239/240	36	Gamma	97.5%KM (Chebyshev)	150	--	--	--
Plutonium-239 ^c	29	--	--	--	29	3	1.2
Plutonium-240 ^c	7	--	--	--	7	1	0.3
Removal of 9.1 m (30 ft)							
Americium-241	21.3	Non-parametric	97.5%KM (Chebyshev)	120	13	1.1	0.42
Plutonium-239/240	40.5	Gamma	97.5%KM (Chebyshev)	130	--	--	--
Plutonium-239 ^c	33	--	--	--	33	3	1.1
Plutonium-240 ^c	7	--	--	--	7	0.6	0.23

Notes:

^aCcut = Cwaste (Lwaste/Lwell)^bCgarden = Ccut (Vcut/Vgarden)^cIndividual radionuclide concentrations were obtained assuming a ratio of 4.4:1 (Pu-239: Pu-240)

Ccut = concentration of a radionuclide/chemical in the well cuttings (pCi/g or mg/kg)

Cwaste = concentration of radionuclide/chemical in the disposal site; maximum or calculated 95 UCL of the analytical data (pCi/g or mg/kg)

Lwaste = thickness of the waste (m)

Lwell = depth of the well from surface to groundwater (m), plus 15.2 m (50 ft), the average depth drilled into the aquifer.

Cgarden = concentration of a radionuclide/chemical in garden soil (pCi/g or mg/kg)

Vcut = volume of cuttings (m³)Vgarden = volume of garden soil (15 m³)

EPC = exposure-point concentration

UCL = upper confidence limit

Table F-7. Summary of RESRAD Input Factors

Factor	Units	Value	Comments
Soil Concentrations			
Basic radiation dose limit	mrem/yr	100	Site specific
Concentration	pCi/g	Cwaste at "Time 0" or Cwaste at "Time 150 years"	Site-specific concentration set manually. Cwaste at "Time 0" is used to estimate the concentration at "Time 150 years." Cwaste at "150 years" is used to estimate the concentration in residential gardens (Cgarden). See Table F-6 for details.
All other soil concentration factors	Varies depending on factor	Varies depending on factor	All default values used
Calculation Times			
1,2,3,4,5,6	years	0, 17, 28, 150, 500, 1000	Site-specific
Contaminated Zone Parameters (for "Time 0")			
Area of contaminated zone	square meters	Site-specific	See Table F-5 for details
Thickness of contaminated zone	meters	Site-specific	See Table F-5 for details
Length parallel to aquifer flow	meters	9.1	Site-specific information used for all sites (9.1 m [30 ft])
Contaminated Zone Parameters (for Residential Garden at "Time 150 years")			
Area of contaminated zone	square meters	100	Site-specific; size of a garden (p. 25, HNF-SD-WM-TI-707)
Thickness of contaminated zone	meters	0.15	Site-specific; tilling depth (p. 25, HNF-SD-WM-TI-707)
Length parallel to aquifer flow	meters	9.1	Site-specific information used for all sites (9.1 m [30 ft])
Cover/hydrol			Contaminated Zone = Hanford Sands
Cover depth	meters	0	Default value
Density of cover material	g/cm ³	Greyed out	Default value = 1.5
Cover erosion rate	m/yr	Greyed out	Default value = 0.001
Density of contaminated zone	g/cm ³	1.85	Hanford Sands = 1.4 – 2.3
Contaminated zone erosion rate	m/year	0	Set to zero
Contaminated zone total porosity		0.3	Hanford Sands value
Contaminated zone field capacity		0.1	Hanford Sands value
Contaminated zone hydraulic conductivity	m/year	1,577	Hanford Sands = 0.005 cm/s; 1,577 m/yr

Table F-7. Summary of RESRAD Input Factors

Factor	Units	Value	Comments
Contaminated zone b parameter		4.05	RESRAD value for sand from Appendix E
Humidity in air	g/cm ³	Greyed out	Default value
ET coefficient		0.5	Default value
Wind speed	m/s	3.4	Site-specific
Precipitation	m/yr	1	Default value
Irrigation	m/yr	0	Assume for Hanford Sands (default was 0.2)
Irrigation mode (overhead or ditch?)		Overhead	Default value
Runoff coefficient		0	Assume for Hanford Sands (default was 0.2)
Watershed area for nearby stream or pond	square meters	1,000,000	Default value
Accuracy for water/soil computations		0.001	Default value
Soil Properties			
Saturated Zone		Ringold	
Density of saturated zone	g/cm ³	1.5	Default value
Saturated zone total porosity		0.33	Ringold value
Saturated zone effective porosity		0.18	Ringold value
Saturated zone field capacity		0.21	Ringold value
Saturated zone hydraulic conductivity	m/yr	7,300	Ringold value = 7,300 m/yr
Saturated zone hydraulic gradient		0.002	Ringold value
Saturated zone b parameter		4.05	RESRAD value for sand from Appendix E
Water table drop rate	m/yr	0.2	Ringold value
Well pump intake depth	meters below water table	10	Default value
Model for water transport parameters (nondispersion or mass-balance)		Nondispersion	Default value
Well pumping rate	m ³ /yr	30,000	10–20 gal/min or approx. 20,000–40,000 m ³ /yr
Number of Unsaturated Zones		3	Number of zones set manually
Unsaturated Zone #1	Soil type	Hanford Sands	Site-specific
Thickness	meters	33.5	33.5 m (110 ft)

Table F-7. Summary of RESRAD Input Factors

Factor	Units	Value	Comments
Density	g/cm ³	1.85	Hanford Sands = 1.4 – 2.3; WHC-EP-0883, Appendix A
Total porosity		0.3	Hanford Sands value; WHC-EP-0883, Appendix A
Effective porosity		0.25	Hanford Sands value; WHC-EP-0883, Appendix A
Field capacity		0.25	Hanford Sands value; WHC-EP-0883, Appendix A
Hydraulic conductivity	m/yr	1,577	Hanford Sands = 0.005 cm/s; 1,577 m/yr; WHC-EP-0883, Appendix A
b parameter		4.05	RESRAD value for sand from Appendix E, Table E-2
Unsaturated Zone #2	Soil type	CCU (silt values; ignored caliche for model)	Site-specific
Thickness	meters	3.1	3.1 m (10 ft)
Density	g/cm ³	2.0	CCU (silt) value; WHC-EP-0883, Appendix A
Total porosity		0.37	CCU (silt) value; WHC-EP-0883, Appendix A
Effective porosity		0.29	CCU (silt) value; WHC-EP-0883, Appendix A
Field capacity		0.29	CCU (silt) value; WHC-EP-0883, Appendix A
Hydraulic conductivity	m/yr	2,740	CCU value = 8.69E-03 cm/s; 2,740 m/year; WHC-EP-0883, Appendix A
b parameter		5.3	RESRAD value for silty loam from Appendix E, Table E-2
Unsaturated Zone #3	Soil type	Ringold	Site-specific
Thickness	meters	32.3	32.3 m (106 ft)
Density	g/cm ³	1.85	Ringold = 1.4 – 2.3; WHC-EP-0883, Appendix A
Total porosity		0.22	Ringold value; WHC-EP-0883, Appendix A
Effective porosity		0.13	Ringold value; WHC-EP-0883, Appendix A
Field capacity		0.13	Ringold value; WHC-EP-0883, Appendix A
Hydraulic conductivity	m/yr	7,300	Ringold = 7,300 m/yr; WHC-EP-0883, Appendix A
b parameter		4.05	RESRAD value for sand from Appendix E, Table E-2

Table F-7. Summary of RESRAD Input Factors

Factor	Units	Value	Comments
Occupancy			
Inhalation rate	cm ³ /yr	8,400	Default value
Mass loading for inhalation	g/cm ³	3.70E-07	Site-specific based on a particulate emissions factor of 2.72E+09
Exposure duration	years	30	Default value
Indoor dust filtration factor		0.4	Default value
External gamma shielding factor		0.7	Default value
Indoor time fraction		0.5	Default value
Outdoor time fraction		0.25	Default value
Shape of contaminated zone		Circular	Default
Ingestion–dietary			
Fruits, vegetables, and grain	kg/year	106	Site-specific value; includes ingestion of fruits and vegetables only
Leafy vegetable	kg/year	10.5	Site-specific value; assuming 9% of fruit/vegetables intake is leafy
Soil ingestion	g/year	36.5	Default value
Contamination fraction–plant food		1	Evaluation of plant food only
Plant factors	Varies depending on factor	Varies depending on factor	All default values used
Radon data	Varies depending on factor	Varies depending on factor	All default values used
Storage times	Days	Varies depending on factor	All default values used

HNF-SD-WM-TI-707, *Exposure Scenarios and Unit Factors for the Hanford Tank Waste Performance Assessment*WHC-EP-0883, *Variability and Scaling of Hydraulic Properties for 200 Area Soils, Hanford Site*

CCU = Cold Creek Unit

RESRAD = RESidual RADioactivity (dose model)

F4.3 Residual Risk Results

The EPCs (garden soil concentration [Cgarden] values) calculated for each removal option were entered into RESRAD to calculate health risks. The site-specific parameters that were entered into RESRAD for each site are presented in Table F-7.

The maximum risk occurs when the subsurface material is initially brought to the surface, assumed to be 150 years in the future. Therefore, the risk results for the various removal options shown in Tables F-8 and F-9 represent risks at the time that the subsurface material is brought to the surface.

Table F-8. Risks and Concentration Changes with Selected Depth Intervals Removed at the 216-Z-1A Tile Field

Depth Interval Removed	Contaminant	Garden Concentration (pCi/g)	Total Risk
6.1 m (20 ft)	Americium-241	4,834	8E-04
	Plutonium-239	4,326	5E-04
	Plutonium-240	972	1E-04
			1E-03
12.2 m (40 ft)	Americium-241	3,381	6E-04
	Plutonium-239	1,952	2E-04
	Plutonium-240	439	5E-05
			9E-04
18.3 m (60 ft)	Americium-241	1,676	3E-04
	Plutonium-239	729	9E-05
	Plutonium-240	164	2E-05
			4E-04
22.9 m (75 ft)	Americium-241	1,120	2E-04
	Plutonium-239	523	6E-05
	Plutonium-240	117	1E-05
			3E-04
24.4 m (80 ft)	Americium-241	874	2E-04
	Plutonium-239	447	5E-05
	Plutonium-240	100	1E-05
			2E-04
27.4 m (90 ft)	Americium-241	268	5E-05
	Plutonium-239	225	3E-05
	Plutonium-240	51	6E-06
			8E-05
30 m (95 ft)	Americium-241	6	1E-06
	Plutonium-239	32	4E-06
	Plutonium-240	7	8E-07
			6E-06

Table F-9. Risks and Concentration Changes with Selected Depth Intervals Removed at the 216-Z-9 Trench and 216-Z-12 Crib

Depth Interval Removed	Contaminant	Garden Concentration (pCi/g)	Total Risk
216-Z-9 Trench			
2.7 m (9 ft)	Americium-241	14,385	2E-03
	Plutonium-239	7,547	9E-04
	Plutonium-240	1,696	2E-04
			4E-03
216-Z-12 Crib			
6.1 m (20 ft)	Americium-241	6,552	1E-03
	Plutonium-239	13,655	2E-03
	Plutonium-240	3,068	4E-04
			3E-03
7.6 m (25 ft)	Americium-241	0.5	9E-08
	Plutonium-239	1.2	1E-07
	Plutonium-240	0.3	3E-08
			3E-07
9.1 m (30 ft)	Americium-241	0.42	7E-08
	Plutonium-239	1	1E-07
	Plutonium-240	0.23	3E-08
			2E-07

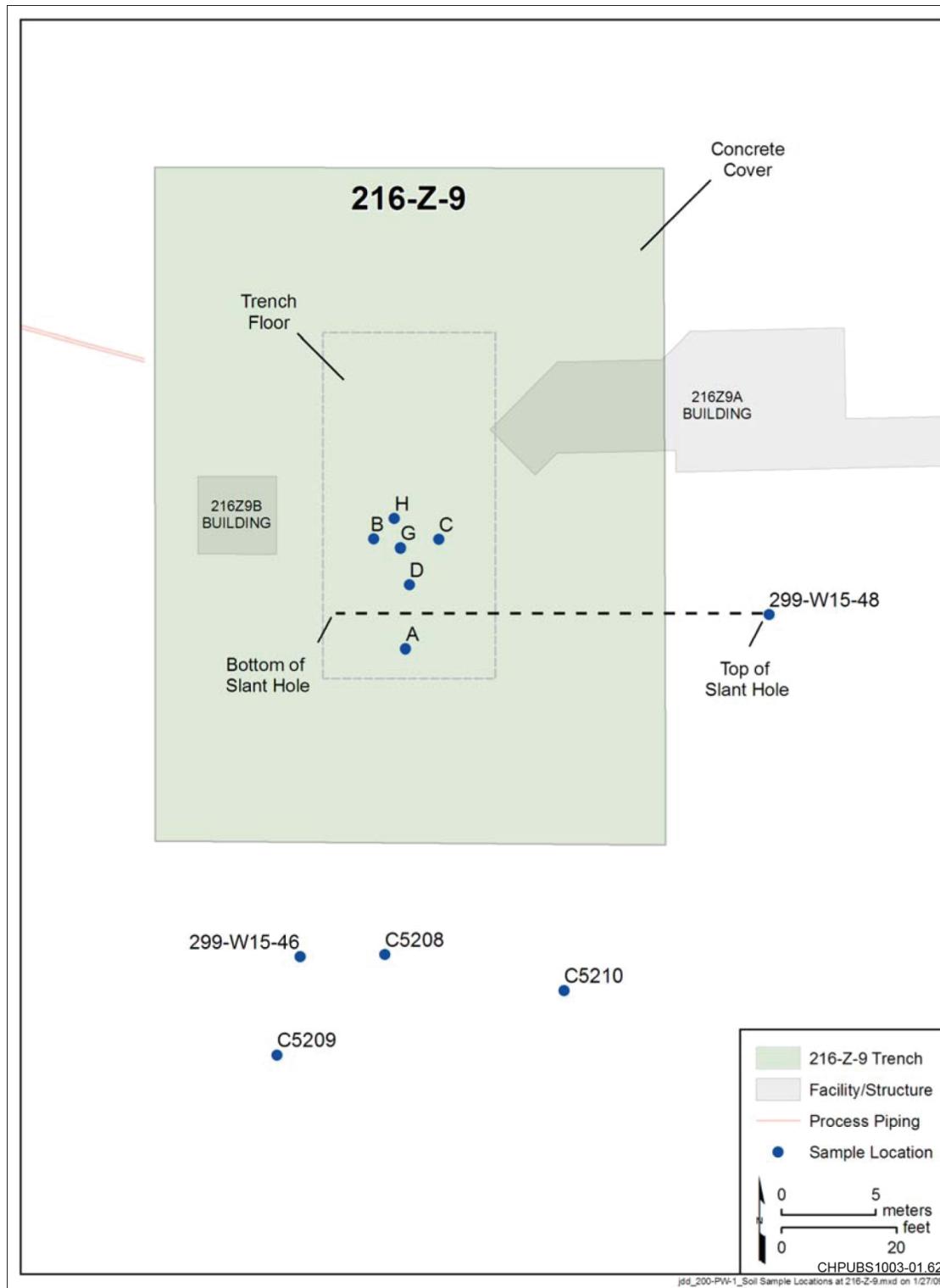


Figure F-7. Soil Sampling Locations at the 216-Z-9 Trench

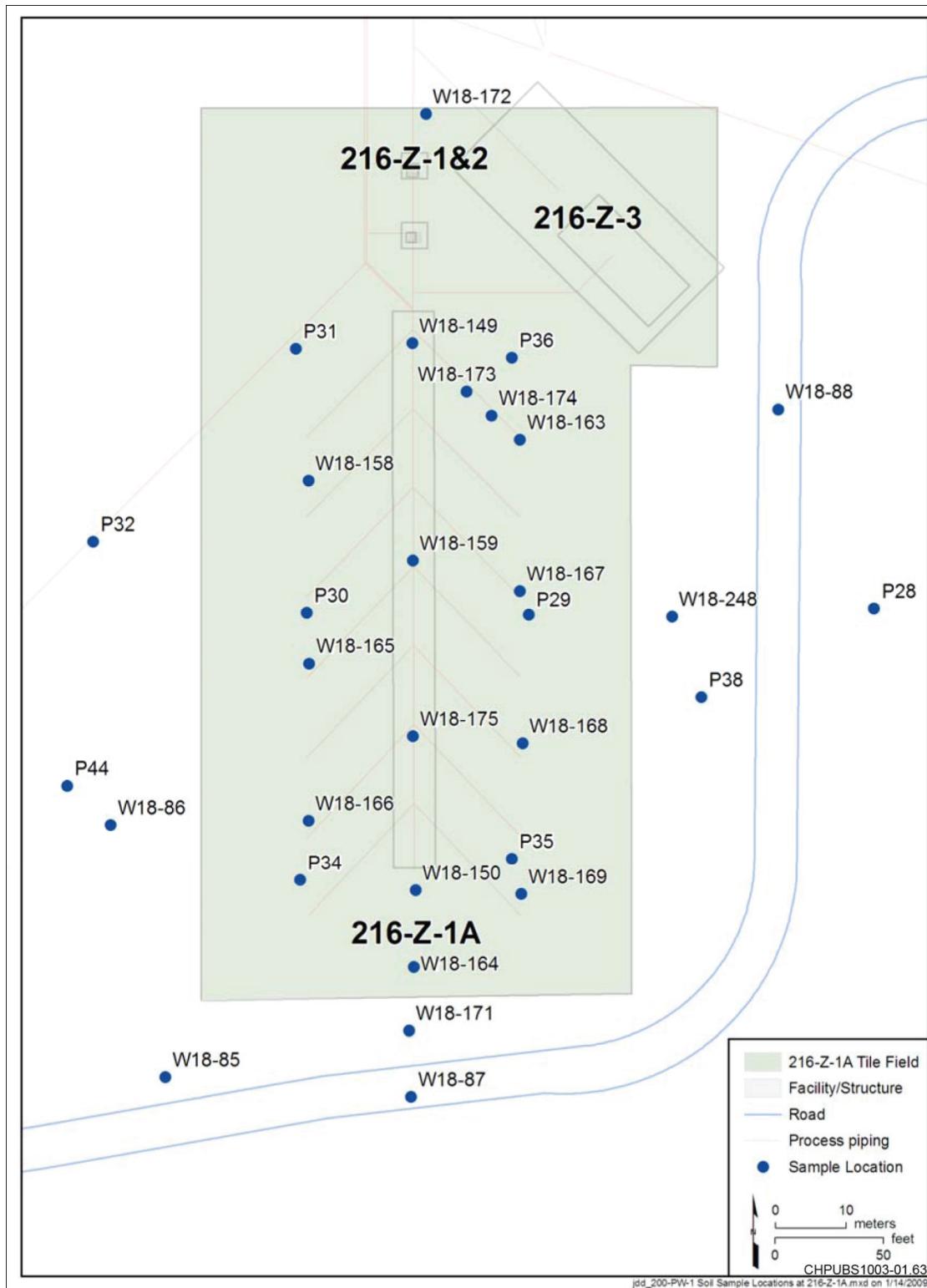


Figure F-8. 216-Z-1A Tile Field Sample Locations for Soil

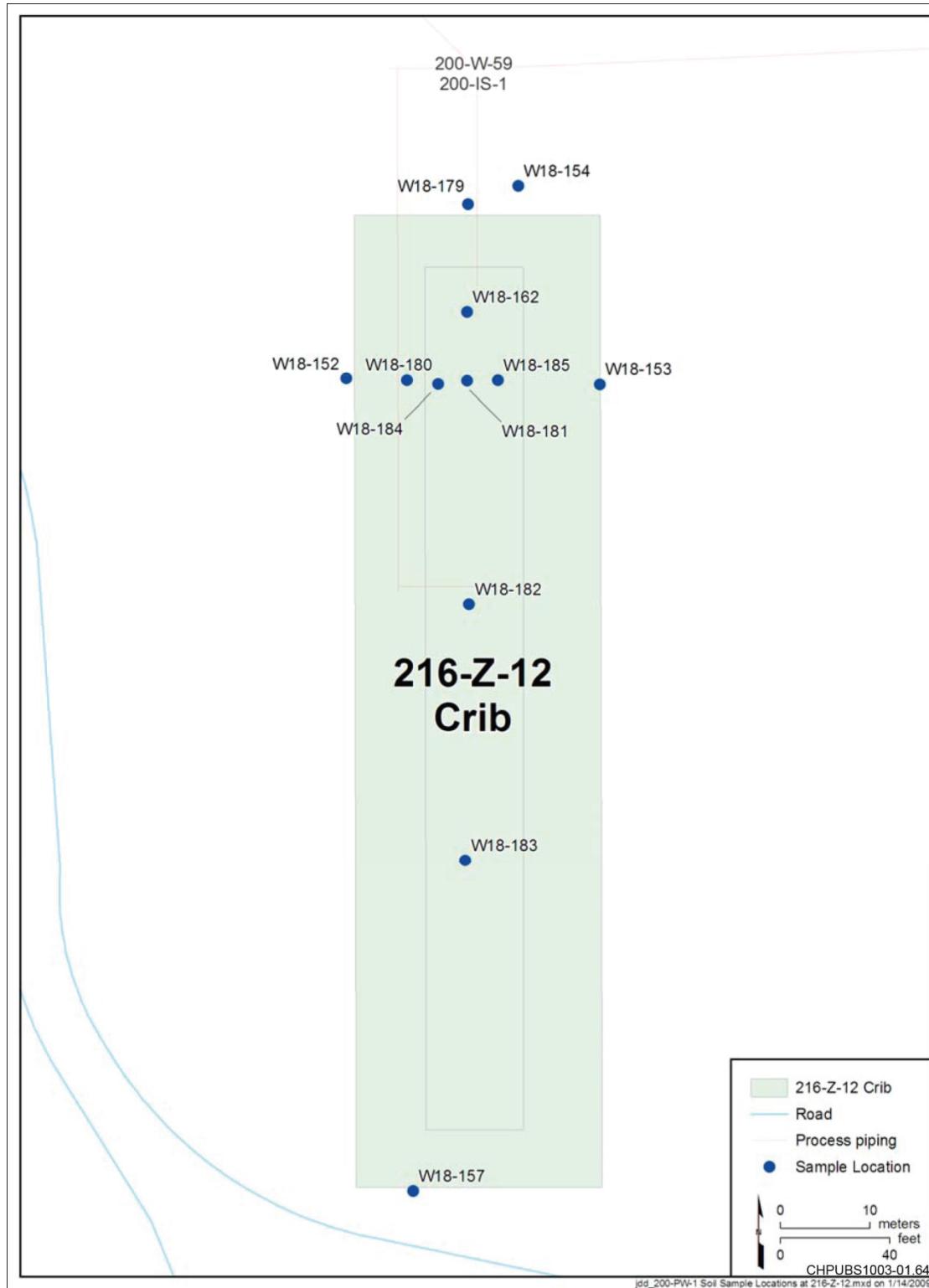


Figure F-9. 216-Z-12 Crib Sample Locations for Soil

Figure F-10 shows a graph of risks for the baseline and seven removal options for the 216-Z-1A Tile Field. Removing 20 m (60 ft) of soil reduces risks nearly two orders of magnitude below the baseline risks and residual risks are within the range of acceptability, a cumulative risk of 4×10^{-4} (considering that 10^{-4} is the acceptable upper risk range, and that EPA allows values above 10^{-4} to remain under certain situations [Clay, 1991; EPA 540-R-97-013]). If 1×10^{-4} is considered a firm target health goal (rather than risks up to 4×10^{-4} as potentially acceptable), then 27.4 m (90 ft) of soil must be removed before risk levels drop below 10^{-4} . The increased removal depth is due to americium-241 concentrations at depth. As shown in Figure F-10, risks from Pu-239 and Pu-240 drop below 10^{-4} after 20 m (60 ft) of soil is removed.

For the 216-Z-9 Trench, baseline risks and risks from the one removal option examined are presented in Figure F-11. Like the 216-Z-1A Tile Field, removal of the most-contaminated soil directly below the trench (the top 2.7 m [9 ft] below the bottom of the trench), also reduces potential future risks by nearly two orders of magnitude, a reduction from 1×10^{-1} to 4×10^{-3} ; however, cumulative risks are still well above 10^{-4} .

For the 216-Z-12 Crib, baseline risks and risks from the three removal options examined are presented in Figure F-12. Removal of the top 6 m (20 ft) below the ground surface only slightly reduces potential future risks, a reduction from 4×10^{-3} to 3×10^{-3} . Removal of an additional 1.5 m (5 ft) for a total removal of the top 7.6 m (25 ft) of soil significantly reduces potential future risks to well below the target goal of 10^{-4} , as well as below the de minimis risk level of 10^{-6} . Cumulative total risks after removal of the top 7.6 m (25 ft) of soil are reduced to 3×10^{-7} .

If the home-grown produce ingestion pathway is not considered in the cumulative risk totals (because this pathway is associated with many assumptions and thus has a high degree of uncertainty) shallower soil depths at 216-Z-1A (and potentially 216-Z-9) than those shown in Figure F-10 and Tables F-8 and F-9 may result in acceptable levels of residual risk remaining. At 216-Z-12, inclusion or exclusion of the produce pathway is unlikely to have an impact – the “break point” for risk reduction appears to be at a depth of 7.3 m (25 ft).

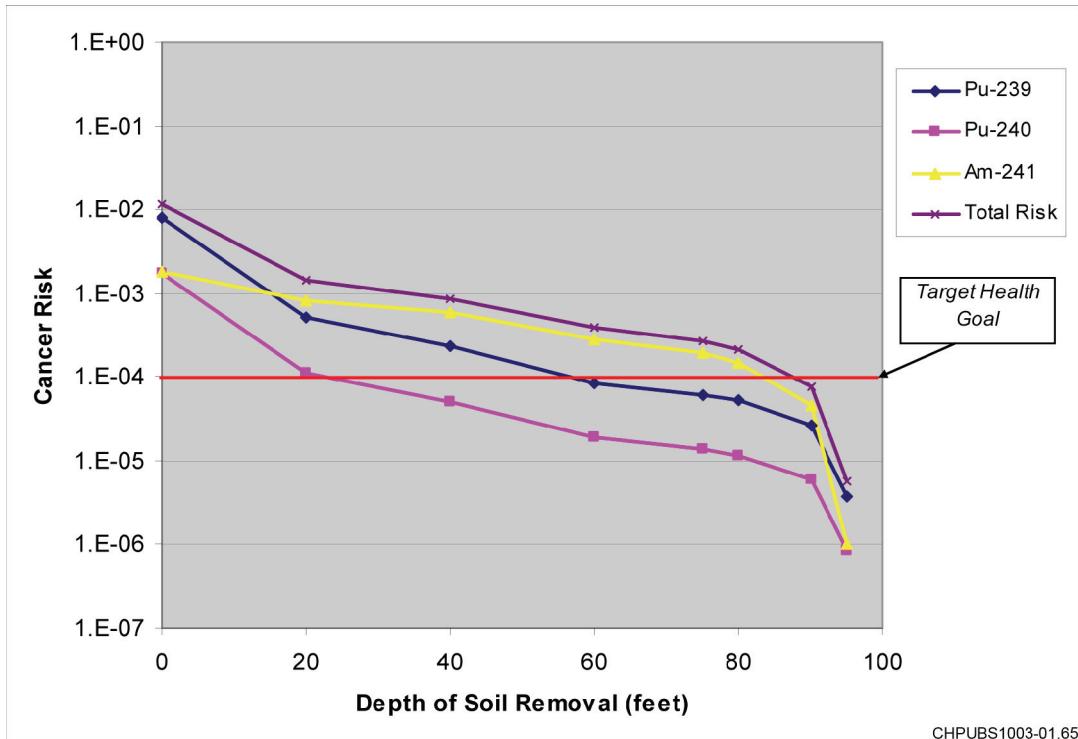


Figure F-10. Risks Compared to Baseline and Different Removal Options at the 216-Z-1A Tile Field

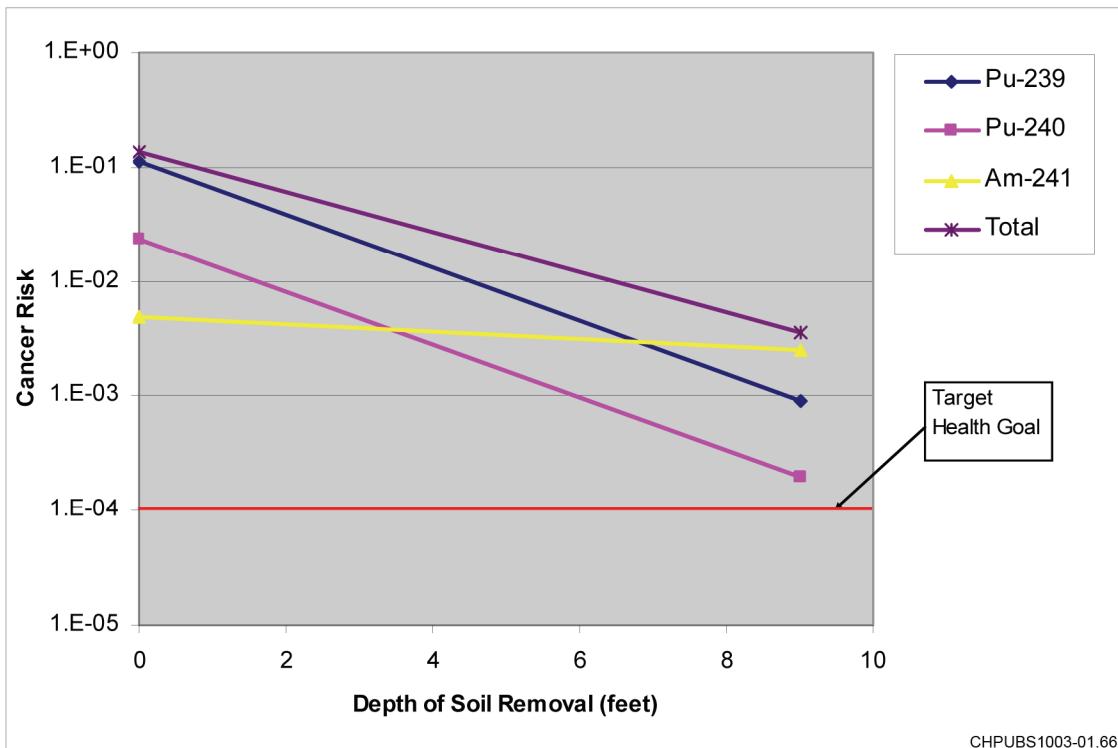


Figure F-11. Risks Compared to Baseline and One Removal Option at the 216-Z-9 Trench

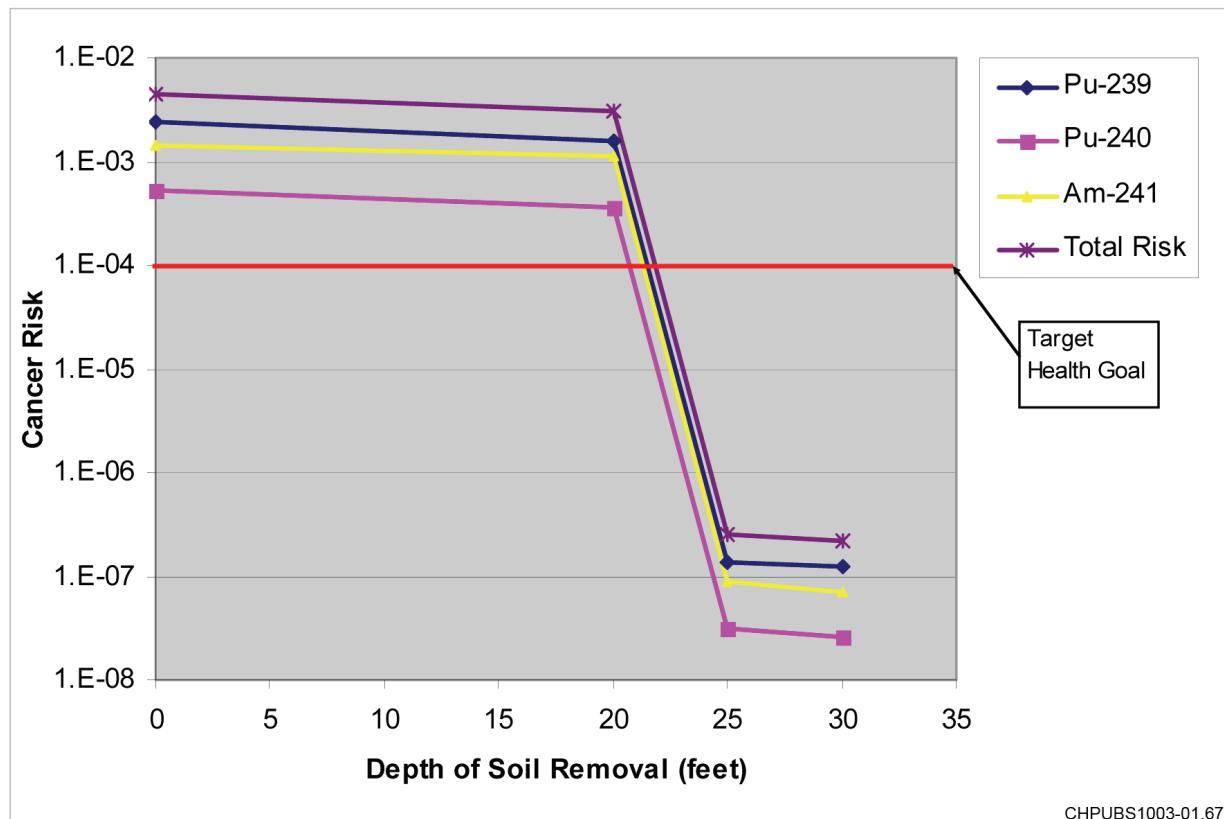


Figure F-12. Risks Compared to Baseline and Three Removal Options at the 216-Z-12 Crib

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